An ex-vivo biomechanical comparison of tension band stabilization and screws and polymethylmethacrylae fixation for lumbar vertebral fractures and luxations in cats

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AN *EX-VIVO* BIOMECHANICAL COMPARISON OF TENSION BAND STABILIZATION AND SCREWS AND POLYMETHYLMETHACRYLATE FIXATION FOR LUMBAR VERTEBRAL FRACTURES AND LUXATIONS IN CATS

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Introduction

Spinal fractures and luxations are frequently diagnosed injuries in cats, affecting around one fourth of all trauma patients with the lumbar spine reported to be the most prone region. The two most common internal fixation techniques for spinal instabilities in cats encompass tension band stabilization and vertebral body stabilization by means of polymethyl-methacrylate (PMMA) and pin or screw composite fixation. In dogs it has been shown that placing an implant on the dorsal tension side of the spine is biomechanically superior over vertebral body plating. Similar data for spinal stabilization techniques in cats are missing. The tension band stabilization technique is preferred by some surgeons because technically simple, low cost, less invasive and fast if compared to screw and PMMA vertebral stabilization. The purpose of this study was to biomechanically test common techniques for spinal stabilization in a feline cadaveric L1-L2 vertebral fracture/luxation model and to define its mode of failure. We hypothesize that 1) tension band technique provides greater stabilization in flexion compared to extension, 2) screw and PMMA fixation provides greater stiffness compared to tension band, and 3) that mode of failure in the tension band technique will be related to the limited dorsal bone stock.

Materials and Methods

Sixteen vertebral specimens of cats were harvested and stored at –20°C for subsequent use. Specimens were randomly allocated to two treatment groups: 1) Screw and PMMA vertebral body stabilization (SP), and 2) tension band stabilization (TS). Mean body weights in the groups SP and TS were 5.0kg and 4.1kg. Biomechanical testing was performed in each specimen for the following consecutive conditions: 1) intact (native), 2) unstable, after incision the L1-L2 intervertebral disc and removal of the L1 endplate, and 3) stabilized.

Surgical Procedure

TS was performed as previously described spanning the segments Th13 to L3. For SP three cortical screws each were inserted in L1 and L2 vertebral body. The segments cranial and caudal to the stabilization were potted for biomechanical testing, leaving three movable segments left in the TS group and one in the SP group.

Biomechanical Testing

Testing was performed using a servo-hydraulic bi-axial testing machine (Instron E3000). First, non-destructive testing was performed to obtain the Neutral Zones (NZ) and the Range of Motion (ROM). The machine was programmed to perform six cycles with continuous loading of 0.25°/sec to 1 Nm in flexion and extension, the predominant motions in the thoracolumbar spine, in each condition. The first three cycles were accounted to overcome viscoelastic creep of the specimen and last three will be used to calculate NZ and ROM. Load to failure was then applied in flexion in C3 at a rate of 1°/sec. Torque and rotation was measured and a load displacement curve was calculated. In the load to failure test, stiffness (Nm/°) and load at failure were determined for each group. Failure was defined as 100% ROM or a sudden decrease in stiffness due to breakage of the fixation. Mode of failure was recorded as well.

Statistical Analysis

Statistical analysis was performed using commercial available statistical software. According to normal distribution either Student t-test or Wilcoxon signed rank test was used. Hysteresis curves (moment-rotation angle) were used to define ROM and NZ for the direction of flexion and extension. Significance was set to $p<0.05$.

Results

In flexion the mean difference (+/-standard error of the mean (SEM)) in rotation of C1 and C3 at a torque of 1Nm was 5.6°+/-1.8° and 15.4°+/-2.8° in flexion and in extension 8.5°+/-1.6° and 26.0°+/-4.9° for the SP and TS group, respectively. Rotation decreased by 387% in flexion and 582% in extension when comparing C1 and C3 in the SP group. In the TS group, rotation decreased 429% in flexion and 305% in extension after implant application compared to the intact condition (C3 vs C1). Comparing reduction in percent of rotation between groups, no significant differences were calculated for flexion ($p=0.077$), whereas percent rotation decreased significantly more in the SP group ($p=0.0188$).

Mean (+/-SEM) ROM for C1 for the SP group was significantly higher with 27.1+/-2.7° compared to C3 with 13.4+/-2.1° ($p<0.0001$). For the TS group, in C1 ROM was 67.8+/-7.0° compared to 26.4+/-2.2° in C3 ($p=0.0001$). NZ for the SP group was 2.7+/-1.3° in C1 and 2.9+/-0.6° in C3. For the TS group, the NZ was 7.49+/-3.1° in C1 and 7.5+/-0.8° in C3.

In the load to failure, the stiffness at 100% ROM of the intact spine was significantly different between groups ($p=0.0446$) with a mean of 0.14Nm/°+/-0.03 for the SP and 0.07Nm/°+/-0.01 for the TS group. The mean torque at 100% ROM was significantly different between groups ($p=0.0049$) with 1.8+/-0.255Nm for the SP and 3.3+/-0.38Nm for the TS group.

In the TS group avulsion of the U-shaped K-wire through the spinous process was the most common mode of failure (n=6) followed by avulsion of cerclages (n=2) and slippage of the U-shaped K-wire out of the cerclage (n=1). In four specimen of the SP group the PMMA column broke over the defect on the side with four screws inserted, in one implant loosening occurred and in four the segment cranial to the stabilized defect broke before implants failed.

Discussion

The objective of this study was to investigate and compare tension band stabilization and screw and PMMA composite fixation for its stiffness and mode of failure. We showed that screw and PMMA fixation was stiffer in extension and flexion when compared to tension band stabilization. Nevertheless, as expected, the differences between groups were less obvious (figure 1) and not significantly different in flexion. Therefore, we confirm our first and second hypothesis.

Weak points of the techniques, as indicated by load to failure testing, are implant avulsion through the spinous process (TS) and PMMA breakage (SP) confirming our third hypothesis. Avulsion or rupture of the figure 8 hemicerclage wire after TS, was clinically reported, but was not observed in the current study.

The strength of our results are limited considering that specimens of different lengths were tested, making comparison between groups difficult. In terms of an internal control, within each treatment group differences between the conditions intact, unstable and stabilized were calculated and analyzed. However, this test-setup was used because SP can be applied to two segments, whereas TS is always applied bridging four segments. Consequently, reduced rotation after stabilization is not only resulting from restricted motion in one segment, rather than three segments. In fact, it cannot be tracked how much motion is reduced in the treated segment without motion capture.

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